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(Article begins on next page)

THE “PROGETTO KRONIO”: HISTORY AND PROBLEMS OF AN EXTREME EXPLORATION IN AN INTACT ARCHAEOLOGICAL DEPOSIT

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SUMMARY: Monte Kronio is a limestone massif fronting the sea near Sciacca, in the eastern part of Sicily; a very active volcanic region. It is well known and has been cited since classical antiquity due to the presence, at the summit (370 m asl), of many cave entrances (Stufe di San Calogero and others) with strong, exiting hot airflow (37°C, RH=100%), which have represented an interest for *calidaria* since the Roman times. In the past centuries, these caves were explored several times, but the hot atmosphere and a shaft allowed very limited visits, which have nevertheless discovered important archaeological deposits belonging to pre-greek civilizations. We will present a general overview and the first microclimatic results made with the aim to understand the structure of cave. The mountain is crossed by very intense airflows, in part entering in the lowest part (Grotta Cucchiara) but the first studies with sonic anemometers in coincidence have shown a strong gap between the known entering and exiting airflows. External and internal thermal and airflow mapping, are showing a complex heat flow structure inside Monte Kronio. The cave complex probably descends to sea level, where it touches a volcanic thermal water table. It is then probable that deeper explorations are going to face higher temperatures and dangerous gases.

KEY WORDS: thermalism, prehistory, Sicily, explorations.

RIASSUNTO: A breve distanza dalla città di Sciacca si alza il monte Kronio ove si aprono le grotte vaporose denominate “Stufe di San Calogero”, di grande interesse dal punto di vista speleogenetico-morfologico e archeologico. La singolarità del fenomeno termale ha richiamato sin dall’antichità l’interesse di studiosi ed esploratori sin dal XVII secolo; è tornata d’attualità dopo le esplorazioni speleologiche realizzate alla fine degli anni ’50 del secolo scorso ad opera degli speleologi di Trieste, quando vennero scoperti i grandi vasi nella Galleria di Milia. Per superare le proibitive condizioni ambientali, temperatura prossima ai 38° C e umidità al limite del 100%, gli speleologi triestini hanno utilizzato tute raffreddate da aria influssa dall’esterno, riuscendo nelle diverse spedizioni ad ampliare notevolmente le conoscenze del sistema termale ipogeo. Quello che sino a qualche decennio fa era conosciuto soltanto come una serie di piccoli antri percorsi da un flusso costante di aria calda, ora è diventata un complesso sistema di cavità interessate dal soffio termale: le Stufe di San Calogero, profonde 56 metri e lunghe mezzo chilometro, sino al punto sinora esplorato, la Grotta Cucchiara, posta un centinaio di metri più in basso, profonda 121 metri per 560 di sviluppo e la Grotta del Lebbroso, che si apre fra le prime due, particolarmente accidentata e dove, presso una galleria che si apre alla base di uno stretto e accidentato pozzo, sono state recentemente rinvenute altre deposizioni di vasi.

PAROLE CHIAVE: termalismo, preistoria, Sicilia, esplorazioni.

MONTE KRONIO: HISTORY OF THE EXPLORATIONS

In the southwestern corner of Sicily, there is a mountain overlooking the Mediterranean, which hides in its depths a mystery: Monte Kronio. It’s a small mountain, just a little higher than a hill (its top reaches the 385 meters), on whose side facing Africa, just below the peak, there are caves emitting hot vapours: the Stufe of San Calogero (Figs. 1-2).

Monte Kronio consists of carbonate rocks (Upper Triassic); on its top stand a monastery and a temple dedicated to the cult of the saint, that tradition has it that he restored the *thermae* driving away demons. The south side is interested by some faults that have led to steep slopes where there are numerous cavities; at the foot of the mountain the layer detritus meets the waterproof cover made of marl and clay, while the northern side slopes gently to the Portolana valley before rising again to 901 m of altitude at Rocca Ficuzza.

From the group of caves next to the peak, hot and humid airstreams come out and condense into columns of steam up to twenty meters high, clearly visible from the town of Sciacca below and from the sea. Hot air comes out from many other vents, for the most part not viable, while the whole plain below is interested by a layer of thermo-mineral waters with a temperature ranging from 32° to 56° Celsius; part of these waters are used for therapeutic purposes by the *Thermae* of Sciacca.



Fig. 1 - View of Monte Kronio from the coast

Nowadays the Stufe are part of a modern thermal resort (Fig. 3) that incorporates all the entrances appropriately canalizing the hot air coming from the bowels of the mountain, but - of course - it was not always so (Fig.

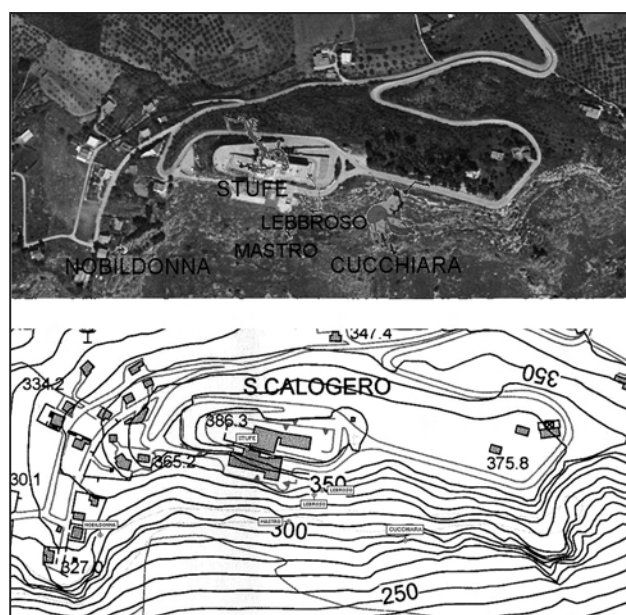


Fig. 2 - Aerial view and general plan of Monte Kronio

4). The initial part of the cavity, a spacious vestibule divided into historical times in different rooms separated by stoneworks, was inhabited by prehistoric man for thousands of years since the first Sicilian Neolithic until the end of Copper Age, leaving a deposit of remarkable consistency that has come to reduce the initial amplitude of the rooms. What strikes the modern visitor is to discover that prehistoric man did not stop here: in the vast galleries below, reached by going down a series of small pits, funerary depositions were found, indicating that the inner part of the cave was already known four thousand years ago. Further traces of human presence (figurines of deities, ritual pots, oil lamps, etc.) can be dated only from the VI-V century BC and can be due to cultural reasons of Greek and Roman populations.

The top of the complex of the Stufe currently consists of several rooms (Figs. 5-6): starting from the west there is the Grotta del Santo (Fig. 5, A), a few-square-meters little room in which is said to have dwelt San Calogero, who is pictured in a tiled panel dating back to 1745 ; an altar



Fig. 3 - Modern thermal baths over the caves

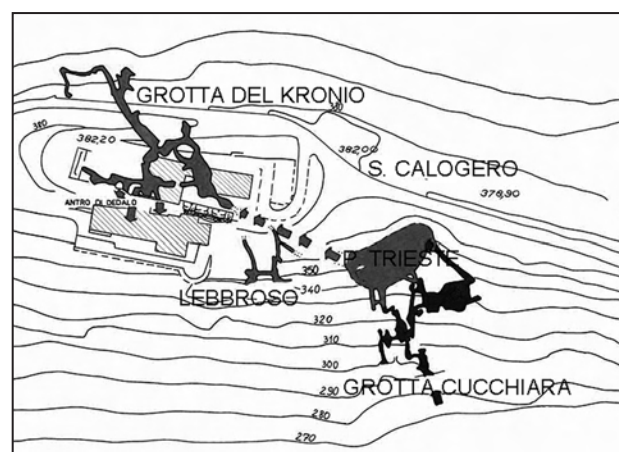


Fig. 4 - Aerophotogrammetry with overlapping of the caves plan (drawings by Commissione Grotte E. Boegan)

characterizes the sacred function of this cave, enclosed by a railing and open to the faithful on the last Tuesday of each month.

Immediately after a space opens up a bit larger, the Stufa degli Animali (Fig. 5, B), once used to cure animals; then we have the Antro di Dedalo (Figs. 5, C; 7), a small room paved with stone slabs and a series of stonework seats placed against the walls, in which is conveyed the greater part of the hot air. It seems that on every seat there was indicated the disease that could be cured there, but unfortunately the writings have been erased at around half of the previous millennium by doctors, it is unclear whether out of jealousy (because patients could treat themselves) or because they believed the writings a nonsense. From the cave a low passage leads to a small room that to the right leads to the Galleria del Fico (Fig. 5, D) and to the left to the wells from which you can reach the lower galleries. All these environments are also connected to each other through narrow conduits, only in part practicable.

BRIEF DESCRIPTION OF MONTE KRONIO

On the southern slope of Monte Kronio were detected about thirty cavities; four of these are interested by remarkable phenomena of air circulation: from two of them - the Stufe and the Grotta del Lebbroso - comes out hot water; from the other two - the Grotta del Gallo and the Grotta Cucchiara - cold air comes in; hot air comes out, in smaller amounts, by cracks (the Fumarole) in the wall of the mountain. Some of the cavities that open at the level of the Stufe (the Grotta delle Pucelle, or Grotta della Nobildonna, Grotta Ciulla, Grotta della Quaquera, Grotta sopra la Cava), blow gently hot vapours (Fig. 2), those placed at lower altitudes have inflowing airstreams, as the already mentioned Grotta Gallo and Grotta Cucchiara, otherwise are neutral.

The Stufe di San Calogero continue, after the part described above, with a series of small pits (m 7, 5, 13) and two large conduits, one uphill and one nearly horizontal, the latter ends with a vertical - the Pozzacchione - at whose base develop some narrow passages, while the hot air comes from a wide window opened over the well. The total depth is 56 meters, with a development of over half a kilometer.

The second cavity of this complex is the Grotta Cucchiara (Figs. 2, 8), also known as the Labirinto Aspirante, which opens almost one hundred metres below the Stufe. A narrow passage under the vault of the initial cave leads to a maze

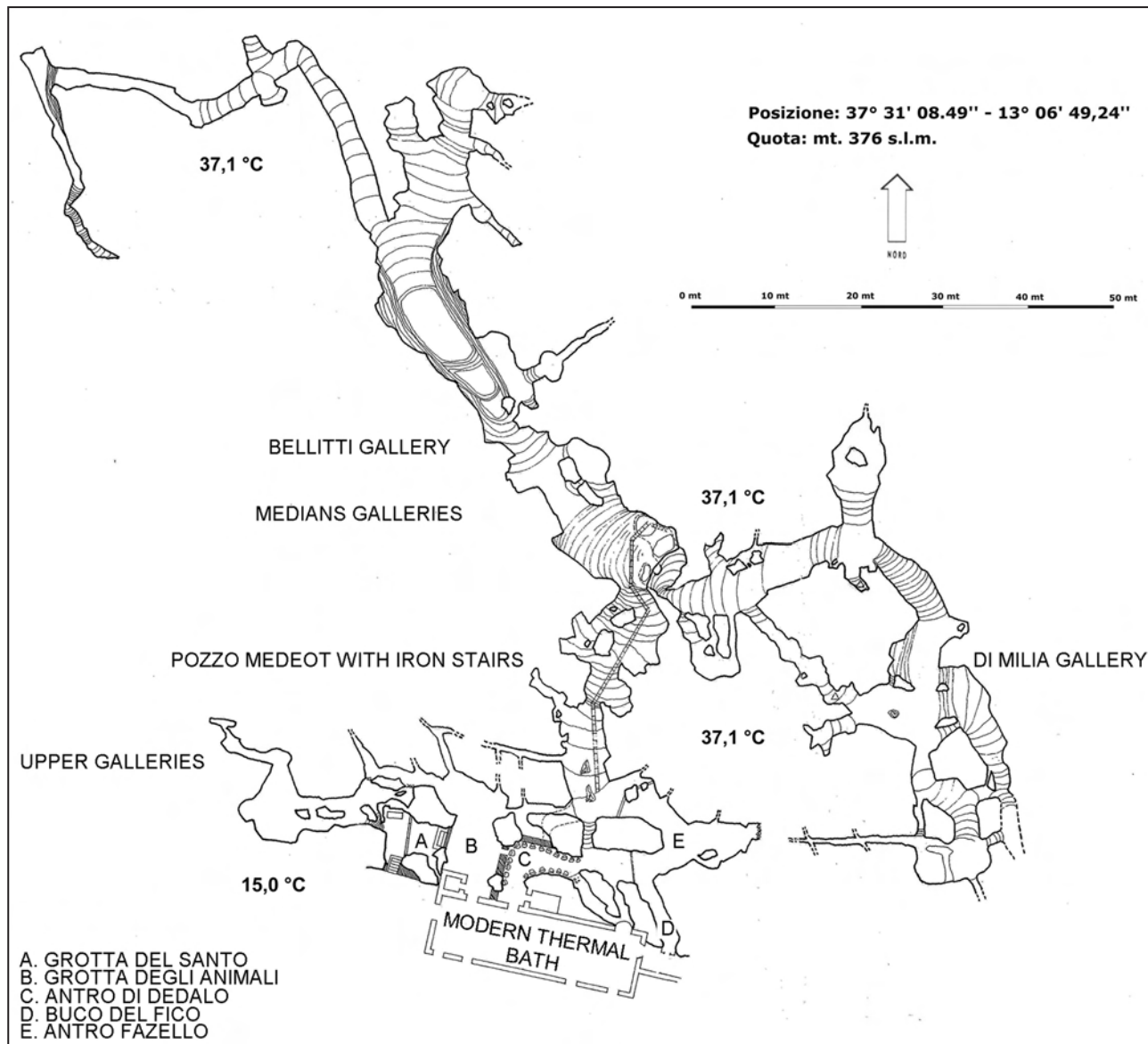


Fig. 5- Plan of the caves complex of Monte Kronio (drawings by Commissione Grotte E. Boegan)

of meatus leading to the Pozzo Trieste, a chasm of more than one hundred meters ending in a vast cavern (over 300 meters of perimeter) without visible continuations (Figs. 4, 6, 9). The hot airflow comes from some windows placed at various heights and disappears towards the Stufe in the large fireplace that is the summit continuation of the pit. From the maze of meatus - the Labirinto - some passages lead to a wide and low cave from which you can again reach the Pozzo Trieste, but at lower altitudes. Many are the verticals affecting this cave: 104 meters of the Pozzo Trieste (measured from the higher access) then 4, 10, 8, 33, +5, +15, +14; the total development is 560 meters with a total depth of 120 meters.

It is part of the still active system even the Grotta del Lebbroso (Fig. 2), a tunnel long 100 m which can be accessed through two entrances, while it ends on a well of 100 m which comes up a considerable mass of warm air. It's situated halfway between the Stufe and the Cucchiara and could be the point of intersection of two major caves.

Special mention also for the Grotta del Gallo (Fig. 2) where, from the access pit (4 metres) you can continue

along a tortuous and narrow passage of 80 cm high and wide just over a meter, going sub-horizontally and with two small pits (five and eight meters deep); the cave, very dry, always aspires a strong air flow (about half cubic metre per second) that is lost in the two inner pits, but that definitely goes into the cauldron from which come the vapours. The system, now being senile, according to the reconstruction made by archaeologists seems to have been reactivated around 4000 years ago by the beginning of the highly aggressive vapourous stream that corrodes the rock and thus alters the original morphology.

THE LEGENDS

A phenomenon of this magnitude - a mountain that breathes hot steams - could not pass without stimulating the imagination of local people. From the corpus of legends and folk beliefs related to the various caves that open stand the stories, some very old, linked to the Stufe of San Calogero.

We start by Diodorus Siculus who tells how *Daedalus*, the supreme architect who dwelled for a long time to *Cocalo* king of the Sikans, after erecting several large buildings

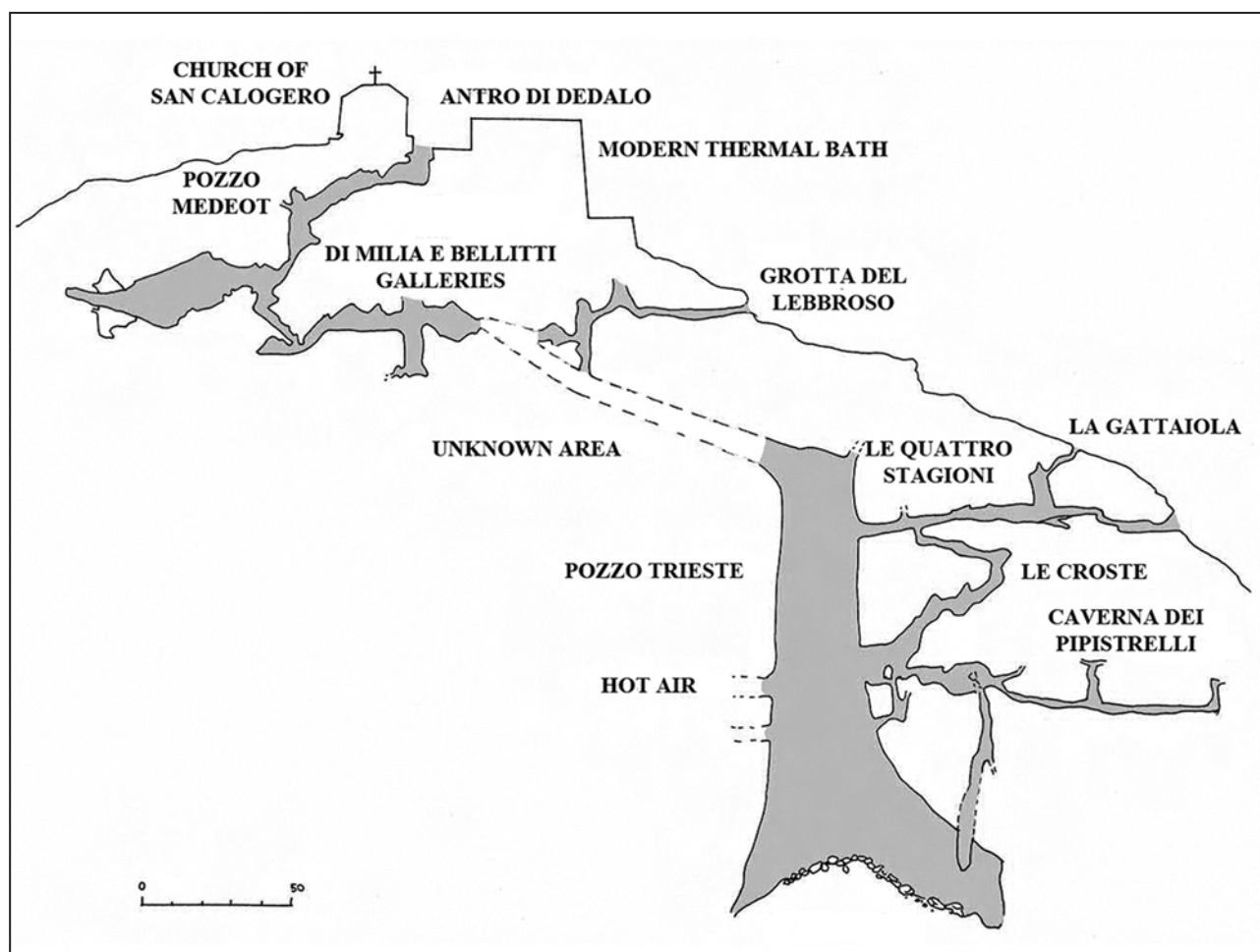


Fig. 6 - Simplified section of the caves complex of Monte Kronio (drawings by Commissione Grotte E. Boegan)

on the island "... built, as the third trial, on the Selinuntina beach a cave from which the smoke evaporated from the fire thus, to those who entered, was caused sweat by effect of the heat, so that the bodies were treated with a certain rapture, without feeling any molestation at all" (Diod. IV, 78, 31), then continuing with a poem of the 9th century that praises of Calogero who chased the demons away from the cave in order to make it usable for people who needing care. The demons-hunter saint had been sent to Sicily in the 6th century by Pope Felix III and the tradition has it that he had lived in one of the minor caves of the complex of the Stufe, precisely the Grotta del Santo.

Even many of the other cavities that open on the southern side of Monte Kronio have their own legend; among the many we mention the one related to the Grotta di Cocalo, where is told that the treasure of Cocalo, the king of the Sicani, is hidden; the Grotta del Lebbroso, a minor cavity affected by the warm flow and in which was cured a leper (who clearly was not admitted to the Stufe ...), and the Grotta della Nobildonna, a small cave where a slight exhalation of steam was used by a lady of a certain class who did not want to mingle with the ordinary sick.

THE CLIMATE

The caves of Kronio would not present technical problems of exploration were it not for the presence of vapours that run through the three most. Vapours which not only bring the rate of humidity close to saturation, but due to

their temperature (36.8° C constant at the exit, often a few degrees higher inside) they prevent the evaporation of sweat, and then the cutaneous thermoregulation of the body. It was ascertained that after about twenty minutes (the time varies from subject to subject) sweating increases dramatically with a consequent decrease of the salts, followed by respiratory difficulties and increased heart rate up to the verge of collapse due to heat stroke.

This problem has been resolved, at least as regards the Stufe and Cucchiara (Fig. 10, 1), by blowing dry air outside (10/15 liters per second) in the suit of the explorer, and this by means of a pipe system which has proved valid for the Stufe and for the first part of Cucchiara. The limits of this system are given by the need to remain connected to the umbilical cord, reducing the space for maneuver, and by the difficulty of properly managing the distribution of air during his descent into the Pozzo Trieste.

THE EARLY EXPLORATIONS

There wasn't new explorations of the innermost part of the Stufe after the visits made at the time of prehistoric man until 1669. In that year the shoemaker Bujela from Sciacca, after repeatedly walking down the initial parts of the cave, got in the inner rooms slipping on the first bench of the well, which leads to low tunnels, where he died. One hundred years later the doctor Antonio Bellitti from Sciacca visited and described the cave down to the inner well; after which the cavity was visited by the French



Fig. 7 - Antro di Dedalo

painter Jean Houel who drew a location plan of the upper part, and by Giuseppe Taurominna who got himself let down, fastened to a rope, until the base of the first drop. In the early twentieth century the cave was investigated by Raffaele Di Milia, who gave a good description, followed shortly by two other citizens of Sciacca. Then, until 1942, there is no news of further explorations.

THE MODERN EXPLORATIONS

In September 1942, in the middle of World War II, the Commissione Grotte of Società Alpina delle Giulie was called by the Head Office of Tourism to carry out an inspection in the Stufe, in order to rationalize the exploitation of the *Thermae*. Two speleologists from Trieste went down into the cavity, Bruno Boegan and Luciano Saverio Medeot. They were the only available, the others being scattered on various fronts of war. On that occasion Medeot descended partially in the inner pit up to the Plateau Noir, detecting it and the upper part of the cavity and drawing up a detailed report.

In January 1957 Medeot, along with contemporary Giulio Perotti, led a small team from the Commissione Grotte to face the pit that had stopped him fifteen years earlier; caving ladders of that time were used: 5 or 6 mm steel cables, wood steps, and who descended was fastened with thick ropes of hemp (Fig. 10, 2). After two days of work a speleologist succeeded in reaching the bottom of the pit (a series of slanted slopes, extremely muddy and slippery, actually) and exploring a gallery (later dedicated to proto-

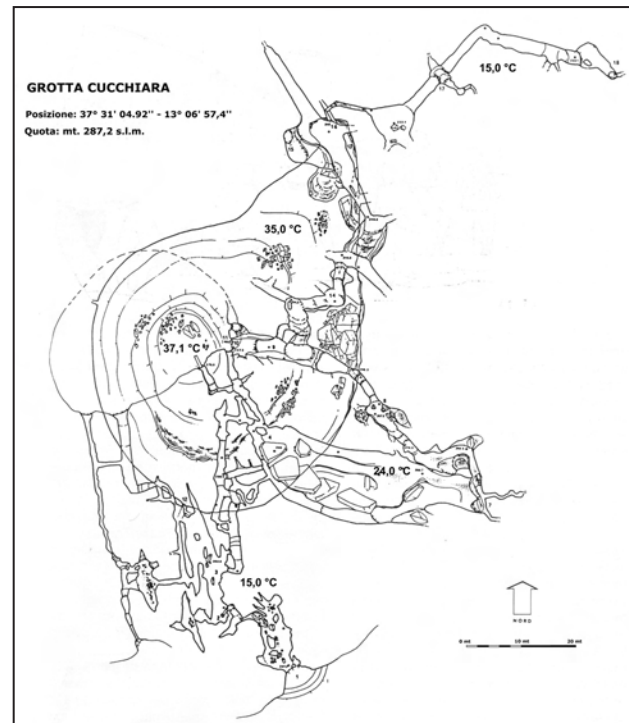


Fig. 8 - Plan of the Grotta Cucchiara



Fig. 9- View of Pozzo Trieste



Fig. 10 - The early explorations of Monte Kronio: 1) speleologist with equipment and mask for cold air; 2) speleologist climbing the Pozzo Medeot; 3-4) speleologists in the Galleria Di Milia with the large Copper age *pithoi*

speleologist from Sciacca Raffaele Di Milia) discovering the vases and the funerary depositions (Fig. 10, 2-3). This exploration showed that without the help of special devices it was possible to remain in the cave for a maximum of 40/45 minutes, long enough to lose an average of two kilograms (of sweat ...) and to be at the verge of collapse.

The importance of the discovery enchanted Perotti and led the Commission to organize another expedition, with the speleologists protected by a thick suit (made with a sail-cloth, at that time still quite in use) in which was blown air produced by a compressor placed on the outside and transported with a series of flexible tubes.

The expedition took place between March and April 1958 and was attended by twelve men among speleologists, archaeologists, journalists and photographers; the gallery discovered the year before was fully explored and a comprehensive photographic documentation was carried out. The suits were revealed conceptually adequate to the task, but very heavy and limiting the movement: for the next expedition - March 1962, the fourth expedition of the Commission - and having archaeological purposes, a suit was made in a lighter material that proved effective enough.

The next expedition, October-November 1974, was organized, always by Perotti - who by then has become the dean of the Stufe - assisted by his colleague Giorgio Coloni, present to all expeditions, for the placement on the wells of a fixed iron ladder, prepared in Trieste in various blocks which were assembled on the spot (Fig. 11, 1). The ladder, greatly easing and reducing descent time, allows to reach the Galleria Di Milia also to those who are not speleologists. In that occasion it was tested a new model of suit, made of very light fabric and equipped with a ventilation system that allows air to get to - and then to cool - the whole body; thanks to the ladder and to these new suits a precision survey was performed and another gallery full of vases was discovered, not detected in previous explorations: the Galleria Bellitti. Still during this campaign it was discovered on the side of the hill a strong suction narrow tunnel communicating with the Grotta Cucchiara: it is a discovery whose true importance will be established in the next expedition, which was carried out in October 1978 and which led to the discovery of a huge fumigant chasm, the Pozzo Trieste.

The preparation of its exploration took a few months and in March 1979 the Triestin speleologists went back on the Kronio; the expedition certainly succeeded, despite two incidents could have inhibited the performance. In fact, despite the fact that on the first week of work two men fell down the iron ladders placed in the Stufe and badly injured themselves, and at the end of the work a technical fault at the hoist placed on the Pozzo Trieste holds temporary up a speleologist on its bottom. In addition to an exploration of the Pozzo Trieste a speleologist succeeded in descending the Pozzacchione, the vertical line that in the Stufe, at the end of the Galleria Di Milia, stopped the previous explorations. The fact that on its basis a complete skeleton with a fractured femur was found puts new open questions on the ancient frequentation of the cavity.

Other expeditions that one might term provisional followed: in 1984 excavations at the Grotta di Gallo in an attempt to locate the path that brings cold air into the bowels of the mountain; in September 1986 setting of cameras in the tunnels of the vases (Bellitti and Di Milia) at the Stufe, discovery of new branches to Cucchiara. In October 1991 the expedition was devoted to the tacheometric detection of the system, the identification in the Cucchiara of new entrants, much lower, to Pozzo Trieste, and the discovery of new breathing caves, until the great expedition of 1998. In late February of that year a dozen speleologists went down to face the vapours of Stufe and Cucchiara including the now elderly Perotti and Coloni. Among the results of this round of work is the discovery of the continuation of the Galleria di Milia beyond the final pit explored in the previous expedition, the observation of the Pozzo Trieste and the identification on its walls of windows from which the vaporous air comes in, the discovery and the detection of a fifteen smaller cavities, some of which are affected by emission of hot air.

THE NEW PHASE TOGETHER WITH THE VENTA TEAM

The new century has seen other exploration trips to the complex of Monte Kronio: the speleologists went down there several times but this time the men of the Commissione Grotte are supported by those of the Associazione Geografica La Venta, forming a synergy of forces, technical and scientific expertise that is proving successful. In 2010, after several informative and reconnaissance inspections that in November 2008 also saw the production of a promotional



Fig. 11 - 1) the iron staircase installed in the Pozzo Medeot in the 1970's; 2) speleologist with the new equipment

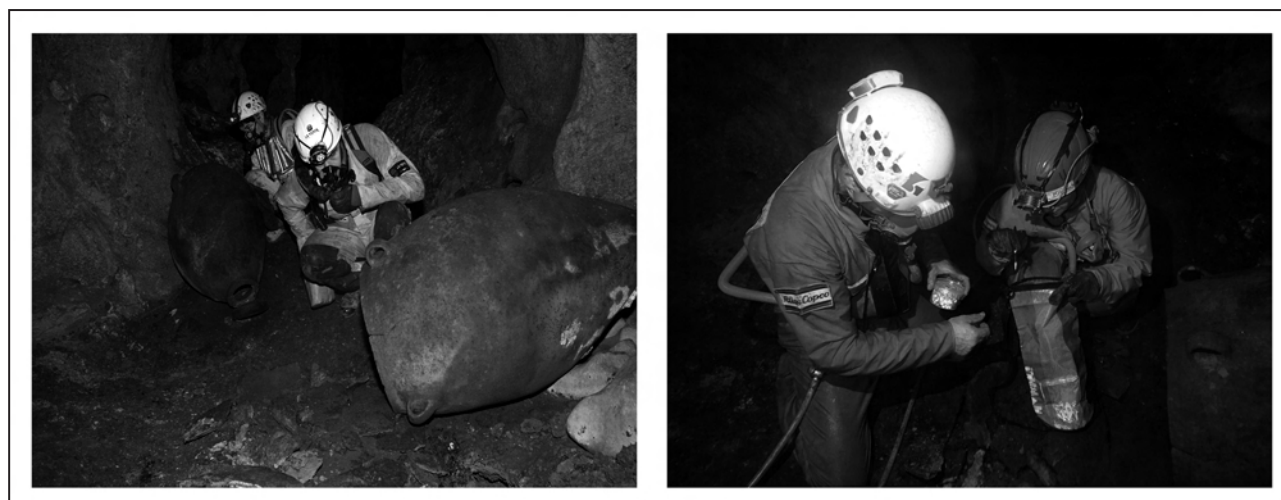


Fig. 12 - Speleologist and archaeologist sampling the content of Copper age depositions for chromatographic analysis

video of great impact, takes place the first expedition of the two groups. New materials and new techniques are tested both in Cucchiara and in the Stufe, where the exploration of the gallery over the Pozzacchione is resumed. A strong scirocco wind, which temporarily blocks the exit of hot air, allows to reach the bottom of the inner well of the Grotta del Lebbroso where the cavity continues with a maze from which the steam comes out.

The main purpose (specifically requested by the Soprintendenza of Agrigento) was to escort some archaeologists within the Stufe di San Calogero, to allow them a first, summary, survey of the vases. The technology in our possession (Fig. 11, 2), together with the experience gained in exploring warm caves, would give the necessary confidence to people not accustomed to such a hostile environment.

It was proceeded to a phase of acclimatization of the new speleologists present for the first time in these caves. In fact it is our intention, for the future, to have a large number of trained personnel that can provide continuity to our Project, as it is a multiannual program and several interventions are scheduled (Fig. 12). It was then re-verified, inside the Stufe, the existence of their continuation, from where the hot steam comes out, but due to the lack of proper equipment we have only set up an iron ladder on a drop of a few meters, which will facilitate future explorations, and made a photographic record of strictly speleological interest. In the cave was created a photographic set to shoot images of the most suitable areas for a future installation of chilled tents for the resting of the archaeologists. Were also conducted additional environmental measurements and installed new instruments.

Of great interest was the arduous task to get down the inner pit the Grotta del Lebbroso, about 25 meters deep (which is reached through a long and difficult narrow tunnel) and invaded by hot steam, therefore with minimum margins of resistance without adequate protection. The stubborn motivation in wanting to proceed to the exploration of this infernal narrow tunnel was due to the belief that they could find the communication with the Stufe and the Pozzo Trieste.

Instead, the discovery of other vases aroused great surprise, making the study of the path followed by our ancestors for their deposition even more complex. The most likely

hypotheses are two: the Stufe continue beyond the farthest point known up to now (where we want to continue with the cooling suits) and then to gets to the Grotta del Lebbroso; or the latter had another entrance, at the level with the basis of its inner pit, now occluded by some collapse.

Still in 2010 other cavities on Monte Kronio were checked, making their positioning with GPS. It is in fact our intention, in the near future, to trace out the position of all the existing caves on the Regional Technical Map, after having made the precision positioning, and to overlap their location plan in order to obtain a “snapshot” of the existing spaces in the mountain. We also visited again some cavities, already known and mapped, also interested by the circulation of air (hot out or cold in) in Monte Kronio. The vastness of the territory affected by such phenomena in fact leads to assume that other discoveries will be made. The maximum distance among the various hot caves so far known is in fact a well of 1600 meters!

The Grotta Cucchiara, located within the reserve of Mount Kronio, was visited several times both to make it known to new participants, and to proceed to the partial recovery of the air pipes, which remained laying on all the way to the cave since 1998, year of the exploration of the Pozzo Trieste. Very interesting was the discovery that large colonies of bats inhabit the cave, no more only in deep zones but also next the entrance.

ARCHAEOLOGICAL RESEARCH

The karstic complex of Monte Kronio is also important because in it there are preserved archaeological remains of inestimable scientific interest. It has been investigated by several archaeological excavation campaigns (1962, 1963, 1969, 1986), carried out in the Antro Fazello, in the Grotta degli Animali and the Grotta del Fico. The purpose of the resumption of underground explorations is to allow to investigate the aspects of the frequentation of the caves during the most recent prehistory, when we suppose that, probably for the purpose of worship, were deposited - in the late Copper Age- many big amphorae. Their location, in fact, is approximate at present, therefore pointing out the need to determine a detailed position and then a precise hypogeum relief (to be made even with the use of laser scanner). Also needed is a close investigation on surface near the depositions as to sample the levels near

the big vases, to make a surface cleaning up and carry out a detailed survey for chrono-typological purposes. It would also be interesting to take samples of soil, within and outside the vases, any their charcols and fragments, to perform analysis of sedimentology, anthracology and micromorphology of soils. Finally, to make thin sections to investigate the origin of raw materials.

It should be understood that the work of the archaeologists should be regularly assisted and supported by the technical and operational contribution of speleologists who are expert on the issues of the Stufe, through the installation of all the means that allow to work under safe conditions for at least a few hours. External air put in special cooled suits and installation of lightweight and non-invasive tents to cover the areas of work and investigation, in turn cooled by the same system; all will be well supported also by the technology gained and tested in Naica (a cave in Mexico where the temperature reaches 50°) by La Venta Group.

It will then be completed the stratigraphic excavation of the Antro Fazello performing a widening of the excavation section of 1986 and verifying, through sampling and micromorphological analyzes, the relations existing layers 16-17 (archaic impressed ware) and the levels rich in faunas difficult to assign (possible presence of Pleistocene fauna). Another option could be to leave part of the section in view even in the aim of educational/touristic use by schools and young people.

CONCLUSIONS AND PLANS FOR THE NEAR FUTURE

There are few caves that have many areas of interest like Monte Kronio. It is an archaeological station of great value that still awaits to be thoroughly investigated, there are considerable biological, physiological and endo-climatic aspects that arouse the curiosity of the researcher, but what prevails it is speleological and archaeological: the solution to the mystery of the origin of the hot air and the connection of the three caves that - for now - are the structure of the system. The steam comes from underground thermal water at an altitude of 60 meters above sea level or from non-practicable meatus connected to volcanic inputs. We want to mention the episode of Ferdinadea island, risen from the sea in front of Sciacca in the mid of the nineteenth century and disappeared shortly thereafter. It's also imperative the study and the archaeological monitoring with the most sophisticated and new systems and equipment, to provide a comprehensive account as to the complexity of the phenomenon and the importance of ancient outcrops with all the related and supplemental implications.

The goals of the Commissione Grotte and of La Venta can be summarized in the determination to complete the physical exploration of the system and make a complete topography of it, carry out the monitoring of the environmental conditions, studies of physiology and microbiology, samplings of minerals, waters, vapours, and to work along with the archaeologists directly employed by the Soprintendenza di Sciacca. All this also in order to develop theoretical models that can justify the evolution in time and space of the vapour phenomenon, inside the caves and with its physical, anthropological and biological contents. Models that could form the basis for a rational planning of the future of the *Thermae* that in the Stufe for thousands of years treat and heal the sick. Of course all this activity would be supplemented and complemented by a photographic and filmed documentation that will bring the beauties and mysteries of the Kronio to an even wider audience.

L. TORELLI

PROBLEMS OF AN EXTREME EXPLORATION

INTRODUCTION

Monte Kronio is a limestone massif fronting the sea near Sciacca, in the eastern part of Sicily; a very active volcanic region. Some 40 km south of Sciacca it exists an underwater volcano (Empedocles), which in 1831 gave rise to the Ferdinanda Island, which quickly disappeared. It is well known and has been cited since classical antiquity due to the presence, at the summit (370 m asl), of many cave entrances (Stufe di San Calogero -now Antro di Dedalo- and others) with strong, exiting hot airflow (37°C, RH=100%), which have represented an interest for *calidaria* since the Roman times. In the past centuries, these caves were explored several times, but the hot atmosphere and a shaft allowed very limited visits (GUIDI, VERDE, 2001).

THE MONTE KRONIO CAVE SYSTEM

Cavers from Commissione Grotte Eugenio Boegan (Trieste) have explored this cave system since 1953, finding important archaeological deposits in the deeper parts, yet not studied (GUIDI 2000); some quick survey have shown that they belong to pre-greek civilizations, some 4000 years ago. Till then the caves were probably used for cultural purposes but abandoned due to the sudden arrive of hot vapour flux. At the end of the 1990s, a total of 1500 m of conduits were known in 30 cave entrances, the most important being Grotta Cucchiara and Antro di Dedalo. Main caves are: Stufe di San Calogero-Antro di Dedalo: 56 m deep, 555 long; Cucchiara: 121 m deep, 560 long; Lebbroso: 23 m deep, 105 long; Mastro Vito Canala: 23 m deep, 64 long.

The Antro di Dedalo and other smaller entrances show a flux of out flowing air, seasonally constant, whilst the Cucchiara flux is inflowing, and then the cave temperature is well below the Dedalo one. The steam flux (more than one million cubic meters per week on average) is probably produced by the contact between the percolation water with the thermal bed, at 70 meters above sea level. The temperature of galleries are around 37 °C; the air is everywhere close to saturation. The Stufe di San Calogero are an ecological niche very different from our physiological needs and they are practically an extension of Earth's deep environment that here nearly emerges: the atmosphere inside this niche seems to belong to another planet. The cave is thought to be the deepest Sicilian cave, but deeper explorations have been impossible until now.

THE KRONIO PROJECT

Few year ago the CGEB, which has performed the explorations in Kronio for more than half century, and

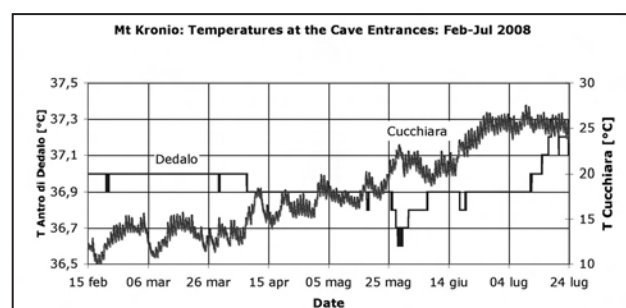


Fig. 13 - Temperatures at the entrances of Grotta Cucchiara and Antro di Dedalo

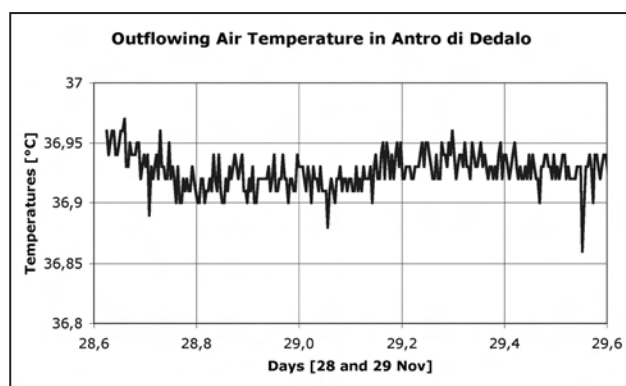


Fig. 14 - Microvariations of air temperature at the entrance of the Antro di Dedalo

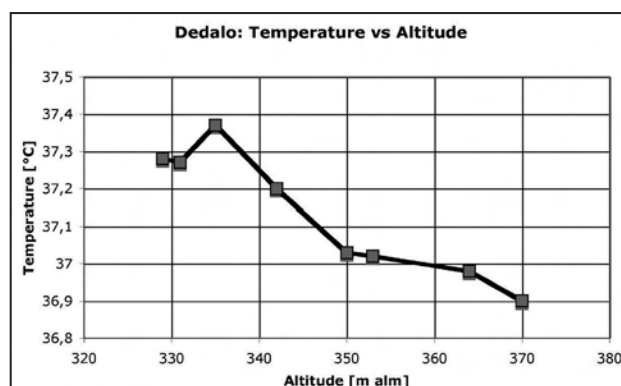


Fig. 16 - Temperature variation in relation to altitude within the Antro di Dedalo galleries

the Associazione La Venta, specialized in international projects of research and documentation about caves, have recently made an agreement to collaborate for a multi-disciplinary project, named "Progetto Kronio", to study this cave system, probably the most extensive in Sicily, and one of the most interesting worldwide from the historical and speleological point of view. The project aim is the full exploration of this cave, in two phases: in the first we will develop devices and techniques to work in these environmental conditions; in the second we will promote the exploration of the Stufe considering different interdisciplinary research fields (archaeology, speleology, biology, geology), helping experts to operate safely underground.

ENVIRONMENTAL CONDITIONS

The air temperature in Antro di Dedalo is around 37 °C, with relative humidity RH=100%. These conditions, which can be sustained for a maximum of 30-40 minutes, are usual in Turkish baths, where nevertheless no physical activity is done. In Monte Kronio caves is necessary a lot of activity both for equipment transport and for moving.

To give an idea of environment hostility we can use the Humidex index, which describes the "perceived temperature", depending on temperature and humidity. A Humidex of 35-39 describes an uncomfortable situation. At 40-45 there is strong and general discomfort, which become extremely dangerous at 46-53. Above the threshold 54 the survival is impossible, there is an imminent heat shock risk and then death.

In San Calogero the Humidex is at 66, well above the deadly level. In fact, the heat shock appears quite suddenly, after a period of general discomfort but without serious problems.

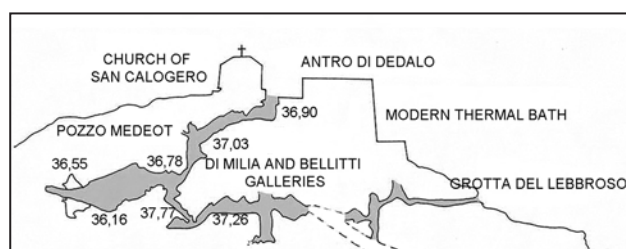


Fig. 15 - Temperature inside the Antro di Dedalo galleries

Then extreme care is needed to avoid approximation at the physiological limits and above all at the exit, as it is necessary to rise 40-50 m of stairs, what can be impossible in case of heat shock.

FIRST MICRO-METEOROLOGICAL RESULTS

In the last years some light researches to estimate temperature variations, air fluxes and technical problems. We are going to show that in fact a careful analysis of micrometeorological parameters can provide useful information about the internal structure of mountain.

The Dedalo and Cucchiara inner temperatures where measured in the period February-July 2008 at 0.1 °C of accuracy. The Cucchiara temperature, not far from entrance, is obviously very near the external one, and it is interesting only to show important meteorological variation.

The Dedalo air temperature is remarkably constant. It shows a significant decrease at the end of May, apparently correlated with a general external temperature increase, and a significant increase at the end of July (Fig. 13).

At the end of November we have measured temperature variation of Dedalo air flux with accuracy 0.01 °C and 5 minutes interval time. In spite of human activity (15 people with powerful lights during the afternoon of 28), its temperature appears to be very stable and not correlated with external temperature variations (Fig. 14). The average temperature was 36.93 ± 0.015 °C. The average amplitude of temperature variation was then around 15 mK!

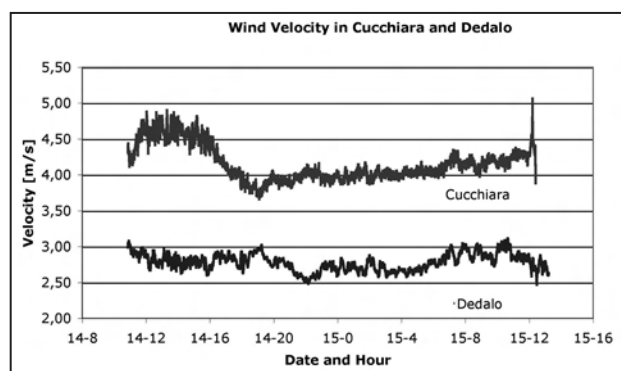


Fig. 17 - Simultaneous measure of wind speeds at the entrances of Grotta Cucchiara and Antro di Dedalo

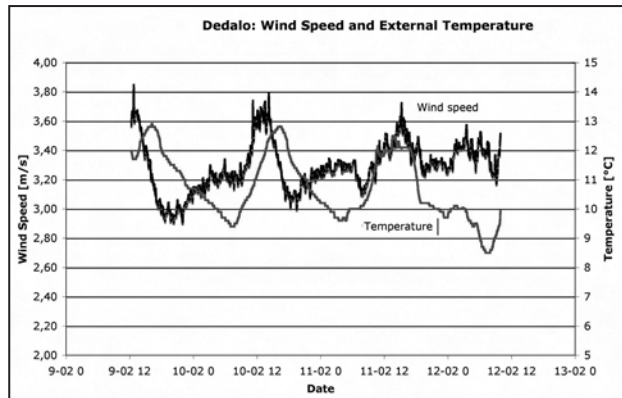


Fig. 18 - External atmospheric pressure and wind speed in the Antro di Dedalo

INTERNAL LAPSE RATE AND CLOUDS

A general map of temperatures of the Antro di Dedalo is given here (Fig. 15). We have not detected any differences between the air temperature at the top and at the bottom of galleries. The strong condensative processes and the turbulent movements are then able to suppress any thermal sedimentation. An internal, stationary clouds results from the condensation due to the global ascending air movement in the Antro di Dedalo, easily observable as a fog in pictures.

It appeared reasonable to suppose that the thermodynamical transformation of ascending air was then moist adiabatic, with its typical cooling lapse rate. In these conditions (altitude 350 m asl and $T=37^{\circ}\text{C}$) the moist adiabatic lapse rate is $-3.2^{\circ}\text{C}/\text{km}$. We have measured the temperature along the descent between entrance and -40 m, with an accuracy of 0.01°C ; results are shown in Fig. 16.

The air temperature regularly increase from the entrance (36.90°C) to the deepest point at -40 m (37.27°C) which corresponds to a cooling rate of $-10^{\circ}\text{C}/\text{km}$, three times more than expected. This shows that the ascending air is cooled by the contact with rocks, two times more than by its expansion.

It is then possible to estimate a temperature of 38°C at 250 m asl. Below this “external” layer we expect rising air be cooled only by its expansion. In this case the temperature of deepest part of Monte Kronio cave system, at sea level, is expected to be around 39°C , with an Humidex of 75.

AIRFLOWS

We made many different measures of airflows. The first has been at Dedalo and Cucchiara, in coincidence, with two sonic anemometers, in the narrowest parts of their entrances, together with external temperature and pressure (Fig. 17). The air velocities are 2.5-3 m/s at Antro di Dedalo and 4-4.5 m/s at Grotta Cucchiara, which correspond to air discharges of $2.5\text{ m}^3/\text{s}$ and $0.6\text{ m}^3/\text{s}$ respectively.

The two air circulations are remarkably constant ($\Delta v < 10\%$), and only the Cucchiara inflow seems to be weakly correlated with atmospheric pressure. The two air discharges do not show any correlation between them and this suggests that the structure of internal airflow is more complex than expected.

This has suggested repeating the comparison between external behaviour of temperature and pressure and the air flux at Antro di Dedalo with higher accuracy. In fact, the air movements inside caves are due to convective movements, which depend on external air temperature (Fig. 18), and atmospheric pressure variations. The comparison can give a more precise idea of cave structure and, above all, of its total volume.

A complex analysis of experimental data has permitted to estimate the total volume of cave which discharge air from the Antro di Dedalo entrance: it looks to be around one million of cubic metres, much more than expected.

CONCLUSIONS

These preliminary micro-meteorological researches suggest that the Monte Kronio cave system is much wider than expected, probably many kilometres long and able to reach the sea level. The archaeological parts are surely the most epidermal, and then the excavations are not going to pose extreme technical problems, but the future deep explorations in a so adverse environment are going to be really difficult and dangerous.

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